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GERMINATION AND EARLY GROWTH OF COASTAL TREE SPECIES ON ORGANIC SEED BEDS

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ABSTRACT

Germination and early growth on rotten wood and duff under several shade levels were observed for Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, Pacific silver fir, and red alder. Nutrients were more abundant in duff than in rotten wood. Seedlings usually were larger and more abundant on duff-covered rotten logs than on duff-covered mineral soil under dense coastal stands. Duff accumulations were thicker on logs and over rotten wood embedded in the soil than over mineral soil alone. Shade limited root growth more than height growth, and seed bed differences limited height growth more than root growth. All conifer species responded similarly to the seed bed and shade differences tested, and type of organic seed bed probably does not affect species composition of forest regeneration under lightly thinned shelterwoods in coastal Oregon. Preserving duff accumulations under shaded conditions benefits early growth of all conifer species.

Keywords: Seed germination, growth factors.

INTRODUCTION

Shelterwood cutting is increasing in coastal forests, largely because it preserves scenic values better than clearcutting. It also creates regeneration conditions quite different from those created by clearcutting--there is less light, less exposed mineral soil, and more organic seed bed material. Most of the forest floor remains covered with accumulations of duff and rotten wood after shelterwood cutting. These accumulations vary in distribution, depth, and state of decay. They are not always equally suitable seed beds. Seeds and seedlings of coastal tree species vary in physiological characteristics and requirements, and each may respond differently to different seed beds. Knowledge of seed bed-species relationships is needed to facilitate seedling establishment and growth and to control species composition under shelterwood canopies.

Germination and early growth on organic seed beds have been studied in several regions. In eastern Canada, balsam fir (*Abies balsamea* (L.) Mill.) and white spruce (*Picea glauca* (Moench) Voss) seedlings often grow on rotten logs and stumps but not on surrounding duff (Place 1955). However, undisturbed duff is a better seed bed than mineral soil for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) on central Montana clearcuts (Hatch and Lotan 1969). MacBean (1941) found that duff supported 40 percent of the western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) seedlings on a logged area on Vancouver Island. When adequate moisture is supplied, hemlock seedlings grow taller on duff than on either rotten wood or mineral soil in British Columbia (Sutton 1954). Western hemlock reproduction is better than that of red alder (*Alnus rubra* Bong.), Sitka spruce (*Picea sitchensis* (Bong.) (Carr.), or western redcedar (*Thuja plicata* Donn) on organic seed beds in coastal British Columbia (Day 1957). It is also better than Sitka spruce reproduction on the organic seed beds of southeastern Alaska (Taylor 1935). Other organic seed bed-species relationships and rotten wood-duff differences are less evident. However, small-seeded species are less successful than large-seeded ones on exposed duff seed beds (Haig, Davis, and Weidman 1941), and shade benefits the germination and survival of most species on most seed beds in British Columbia (Garman 1955).

In the three studies presented here, organic seed beds and coastal Oregon tree species were compared to determine seed bed-species relationships.

FIELD OBSERVATIONS

General observations in coastal Oregon forests indicated that seed bed relationships are influenced by shade. In heavy shade (less than 10 percent full sunlight as measured by a Weston Model 756 illumination meter[1/]), most coastal

[1/] Mention of a product does not imply endorsement by the U.S. Department of Agriculture.

Oregon conifer seedlings occur on rotten logs, not on the duff-covered forest floor. Rotten logs also are better seed beds than forest-floor duff in moderate shade (10 to 40 percent full sunlight). Both rotten logs and forest-floor duff are excellent seed beds in light shade (40 to 60 percent full sunlight). Both are unsatisfactory seed beds in full sunlight.

Paired plot observations were used to compare the occurrence and heights of native Sitka spruce and western hemlock seedlings on rotten log and forest floor seed beds in moderate shade. These plots were established in stands less than 6 kilometers from the ocean at Cascade Head Experimental Forest near Otis, Oregon. A rotten log comprised one rectangular plot in each pair. A second plot was established by marking off an equal area on the forest floor 1.2 meters away. A coin flip determined offset direction perpendicular to the long axis of the log. The two plots in each pair were of equal size and shape, but sizes and shapes differed among pairs as log sizes and shapes differed. All spruce and hemlock seedlings less than 2 meters tall were counted on each plot, heights of the tallest seedlings of each species on each plot were measured, and the area of each plot was calculated. The resulting height and density data were subjected to analyses of variance. Both species were taller and more numerous on rotten logs than on the forest floor (table 1).

Table 1.--*Average seedling density and heights of tallest seedlings on moderately shaded seed beds, by seed bed type and species*

Seed bed	Average number of seedlings per square meter[1/]		Average height of tallest seedling[2/]	
	Spruce	Hemlock	Spruce	Hemlock
			- - - Centimeters - - -	
Rotten logs	16.8	52.1	44.7	55.1
Adjacent forest floor	10.3	23.0	24.9	43.9

[1/] Density differences for both seed beds and species are highly significant (p = 0.99).

[2/] Height differences for seed beds are significant (p = 0.95) and for species, highly significant.

Thornburgh,[2/] working in the Cascade Mountains of Washington, noted that small hemlock seedlings reach maturity only on those rotten logs which have a solid, undecayed core surrounded by a thin shell of rotten wood. This limitation of seedling maturation to a specific log condition was not observed

[2/] Dale A. Thornburgh. Dynamics of the true fir-hemlock forests of the west slope of the Washington Cascade Range. 210 p., 1969. (Unpubl. Ph.D. thesis on file at Univ. Wash., Seattle.)

in coastal Oregon. Both seedling and mature hemlock and Sitka spruce trees were found on logs with both solid cores and cores in several stages of decay (fig. 1).

Figure 1.—Three hemlocks growing on a completely rotten log. The smallest seedling at left (roots exposed) is 18 years old and 2 meters tall. The middle tree is 8-centimeters d.b.h., and the large tree at right is 60-centimeters d.b.h.

Logs on which seedlings were growing were compared with the surrounding forest floor to determine why the logs made better seed beds in moderate and heavy shade than the forest floor. Apparently moisture differences between forest floor duff and rotten wood were not responsible. Although rotten wood retained more moisture than duff, both remained moist throughout the summer in the heavily shaded areas where seed bed differences were most evident. Nor did log elevation above the surrounding forest floor seem to be responsible for the log-forest floor difference. Occasional hemlock seedlings were found growing on the level forest floor in heavy shade but only over buried pieces of rotten wood (fig. 2). The forest floor duff seemed thicker over these buried pieces of rotten wood than over the adjacent mineral soil. Reexamination of the rotten logs showed that those logs supporting seedlings also had thick duff accumulations. Accordingly, paired measurements of duff thickness on rotten wood and mineral soil were made in 50 shaded areas. The duff varied greatly, but accumulations were significantly thicker over buried pieces of rotten wood and on the tops of rotten logs where seedlings occurred than they were over mineral soil. Duff apparently decomposes more slowly over rotten wood than it does over mineral soil.

Figure 2.–Uprooted hemlock seedling with roots embedded in buried rotten wood.

LABORATORY EXPERIMENTS

Methods

To test organic seed beds under controlled conditions, rotten Douglas-fir wood and hemlock duff were collected on the Cascade Head Experimental Forest. Each material was air-dried, screened through 8-millimeter mesh, blended to insure uniformity, and chemically analyzed. Clay pots were filled with weighed quantities of the seed bed materials, then immersed in water to the pot collars. After both rotten wood and duff seed beds were saturated, equal numbers of seeds (all of the same species) were placed on the seed bed surface in each pot (fig. 3). Douglas-fir, Sitka spruce, lodgepole pine, western hemlock, western redcedar, Pacific silver fir, and red alder seeds from low-elevation coast sources were used. Each seed bed-species combination was replicated five times. All pots were covered with polyethylene to prevent drying of seeds. They were then placed in a growth chamber set for 16-hour, 20° C. days and 8-hour, 8° C. nights. A combination of incandescent, cool white, and warm white fluorescent lamps provided 1,500 foot-candles of light at the seed bed surfaces.

Figure 3.–Seed beds in the growth chamber. Polyethylene pot covers kept the seeds moist, and the pots were watered from below by filling the lower containers.

Seed beds were kept moist by watering from below until germination was complete and then watered regularly from above. Germinating seeds were counted every 3 days, and the total numbers of germinating seeds in each seed bed were compared by analyses of variance. Germination rates, as determined by the number of days required for germination to be 50 percent complete in each pot, were also compared by analyses of variance.

The seedlings were grown for 16 weeks in the growth chamber, then harvested, ovendried, and weighed. Seedling survival, based on the number of germinating seeds, was compared among seed beds by analysis of variance for percentages based on unequal numbers (Cochran 1943). Total weights of the largest seedling in each pot were also compared among seed beds by analyses of variance. Scheffé tests (Snedecor and Cochran 1967, p. 271) were used to compare species survival on each seed bed, and Tukey tests (Snedecor 1956, p. 251) were used to compare species weights.

A second growth chamber experiment was conducted under identical conditions, but with additional nutrients to see if seed bed differences were related to nutrient deficiencies. The seed bed materials were initially saturated in nutrient solution,[3/] and equal quantities of this solution were added weekly until the seedlings were harvested. Growth periods, harvesting, data gathering, and statistical analyses were identical in the two experiments.

RESULTS

Nitrogen content in hemlock duff (1.239 percent) was six times greater than in rotten Douglas-fir wood (table 2). Extractable phosphorus (648 parts per million) was seven times greater. These nitrogen and phosphorus contents also greatly exceed the 0.1 to 0.3 percent nitrogen and 10 to 200 parts per million available phosphorus found in virgin forest soils (Wilde 1946). Other nutrients also were more abundant in duff than in rotten wood or a forest soil.

The germination rates of all species were slower on duff than on rotten wood in the first growth chamber experiment, but Douglas-fir was delayed significantly longer than the other species. Variations in seed lot viability make among-species comparisons of germination percentages statistically invalid. Within-species comparisons (table 3) show that seed bed materials did not affect germination percentages.

Within-species survival comparisons show that Douglas-fir survived better on rotten wood in the first experiment, and red alder survival was better on duff. Survival of the other species was not affected by seed bed material. Comparisons of survival among species showed no significant species differences on either duff or rotten wood.

[3/] 1.6 grams $Ca(NO_3)_2$, 1.0 gram KNO_3, 0.5 gram $MgSO_4$, and 0.3 gram KH_2PO_4 per liter of H_2O.

Table 2.--*Chemical analyses of seed bed materials used in the growth chamber and in the field*

Seed bed	Total nitrogen 1/	Phosphorus		Potassium		Total calcium 6/	Total magnesium 6/
		Total 2/	Extractable 3/	Total 4/	Exchangeable 5/		
	Percent	*Parts per million*					
Growth chamber:							
Hemlock duff	1.239	1,337	648	950	828	2,340	1,585
Douglas-fir wood	.212	123	90	240	218	925	425
Field:							
Hemlock duff	1.096	1,230	325	635	614	1,750	2,325
Douglas-fir wood	.104	72	45	210	210	700	275
Sitka spruce wood	.135	129	45	245	215	940	530
Hemlock wood	.098	72	50	140	108	1,220	550

1/ Kjeldahl.
2/ Colorimetric, after perchloric acid oxidation.
3/ Sodium bicarbonate extraction.
4/ Flame emission after perchloric acid oxidation.
5/ Ammonium acetate extraction.
6/ Atomic absorption after perchloric acid oxidation.

Table 3.--*Average seed germination, survival of germinated seedlings, and weight of largest seedling in a growth chamber, by species and seed bed material*

Species	Average germination			Average survival of germinated seedlings 1/			Average weight of largest seedling		
	Duff	Rotten wood	Significance of difference 2/	Duff	Rotten wood	Significance of difference 2/	Duff	Rotten wood	Significance of difference 2/
	- -*Percent*- -			- -*Percent*- -			- - -*Grams*- - -		
Red alder	80	82	NS	92	66	**	1.42	0.01	**
Douglas-fir	56	78	NS	61	76	*	.53	.13	*
Sitka spruce	42	40	NS	73	91	NS	.49	.03	**
Lodgepole pine	92	92	NS	65	61	NS	.37	.07	**
Western hemlock	79	84	NS	69	62	NS	.29	.03	**
Western redcedar	74	94	NS	56	54	NS	.34	.02	*
Pacific silver fir	28	40	NS	47	54	NS	.29	.12	NS

1/ Based on number germinating.

2/ Statistical significance of seed bed difference--NS = not significant, * = significant (p = 0.95), ** = highly significant (p = 0.99).

Seedlings of all species were heavier on duff than on rotten wood. Alder seedlings were significantly heavier than all others on duff, lighter than all others on rotten wood. Douglas-fir and Pacific silver fir seedlings were significantly heavier than all others on rotten wood.

When nutrients were added in the second growth chamber experiment, no seed bed-induced differences in germination rates were observed. Sitka spruce germination was better on rotten wood than on duff, but the germination of other species was not affected by seed bed material (table 4).

Adding nutrients did not significantly affect the relative survival of red alder, western redcedar, or Pacific silver fir on the two seed beds--red alder survival was again better on duff, and the survival of western redcedar and Pacific silver fir remained unaffected by seed bed materials. However, the added nutrients did significantly alter the relative survival of all other species. They all survived better on duff than on rotten wood when nutrients were added. The added nutrients improved growth on rotten wood, but seedlings grown on duff were again heavier than those grown on wood.

Alder seedlings germinating on duff were quite different from those germinating on rotten wood. The germinating seedlings produced abundant root hairs on the duff, and the young roots were unbranched. No root hairs were produced on the rotten wood, and the young roots branched while still above the seed bed surface. Root development remained different on different seed beds as the alder seedlings grew larger--root nodules were produced on duff, but not on rotten wood. These differences in alder germination and root development occurred in both experiments.

FIELD EXPERIMENT

Methods

Seed bed materials were collected, prepared, and sampled as done in the growth chamber experiments, except that three species of rotten wood were used--Douglas-fir, Sitka spruce, and western hemlock. Rotten log species were identified by using a field key (Minore 1966). Rotten wood was then collected from several logs and blended to yield a uniform composite sample for each of the three species. Hemlock duff was used as a fourth seed bed material. The four seed beds were combined with three shade intensities in a completely random, split-plot design in which shade treatments were the main plots, and seed beds were the subplots.

The seed beds and shade treatments were established in a level field on the Cascade Head Experimental Forest at an elevation of 50 meters. Each subplot consisted of a 15-centimeter-deep hole 30 centimeters in diameter. This hole was lined with a bottomless cylinder of copper window screen, then filled with one of the seed bed materials. There were 15 holes for each of the four materials. They were spaced 1.2 meters apart. Hardware cloth cones were

Table 4.--*Average seed germination, survival of germinated seedlings, and weight of largest seedling with added nutrients in a growth chamber, by species and seed bed material*

Species	Average germination			Average survival of germinated seedlings[1]			Average weight of largest seedling		
	Duff	Rotten wood	Significance of difference[2]	Duff	Rotten wood	Significance of difference[2]	Duff	Rotten wood	Significance of difference[2]
	- -Percent- -			*- -Percent- -*			*- - -Grams- - -*		
Red alder	88	90	NS	94	61	**	4.15	1.33	**
Douglas-fir	76	76	NS	74	41	*	1.15	.68	*
Sitka spruce	38	74	**	73	59	**	.63	.37	*
Lodgepole pine	96	94	NS	86	43	**	.60	.26	**
Western hemlock	96	96	NS	92	66	**	.30	.20	NS
Western redcedar	88	90	NS	69	46	NS	.83	.22	*
Pacific silver fir	46	44	NS	0	4	NS	--	.11	--

1/ Based on number germinating.

2/ Statistical significance of seed bed difference--NS = not significant, * = significant (p = 0.95), ** = highly significant (p = 0.99).

placed over each of the 60 filled holes to provide protection from rodents and birds (fig. 4). These hardware cloth cones alone provided the light shade treatment of 79 percent full sunlight.[4/] Porous Saran plastic shade-screen material placed over the hardware cloth provided the moderate and dense shade treatments of 43 percent and 2 percent full sunlight, respectively. Seed bed materials and shade treatments were randomly distributed, and each seed bed-shade combination was replicated five times.

Figure 4.—Artificial seed beds in the field. Light, moderate, and heavy shade conditions were obtained with the hardware cloth and shade screen cones shown here.

In November 1967, the seed beds were seeded with six species: Douglas-fir, Sitka spruce, lodgepole pine, western hemlock, western redcedar, and Pacific silver fir. With the aid of a plastic template, 10 seeds of each species were sown on each of the 60 subplots in the same random order. They were loosely covered with 1 centimeter of seed bed material immediately after sowing.

The seed beds were not watered, but soil between the subplots was cultivated during the spring and summer of 1968 to prevent weed growth. Seedlings were counted monthly to determine germination percentages. The survivors were harvested in October, when the following counts and measurements were made for each subplot: (1) Number of surviving seedlings, (2) height of tallest seedling of each species, (3) root length of tallest seedling of each species, and (4) ovendry shoot, root, and total weights of tallest seedling of each species. These data were then subjected to analyses of variance. Individual treatment averages were compared by Scheffé tests.

Results

Within-species differences in germination and survival on the four seed beds were small (tables 5 and 6), but initial germination was better on rotten

[4/] All shade intensities were measured at noon on a cloudless day with a Weston Model 756 illumination meter reading at 4,700° K.

Table 5.--*Average seed germination in the field, by species, seed bed material, and shade treatment*[1/]

Species and seed bed	Shade treatment			Average, all shade treatments
	Light	Moderate	Heavy	
	- - - - - - - - - - - -	*Percent*	- - - - - - - - - - - -	
Douglas-fir:				
Duff	80	54	48	60.7
Douglas-fir wood	62	72	78	70.7
Spruce wood	72	46	60	59.3
Hemlock wood	74	86	52	70.7
Average, all seed beds	72.0	64.5	59.5	--
Sitka spruce:				
Duff	24	36	30	30.0
Douglas-fir wood	46	56	32	44.7
Spruce wood	68	24	22	38.0
Hemlock wood	32	46	28	35.3
Average, all seed beds	42.5	40.5	28.0	--
Lodgepole pine:				
Duff	88	48	54	63.3
Douglas-fir wood	68	68	58	64.7
Spruce wood	76	36	46	52.7
Hemlock wood	44	46	30	40.0
Average, all seed beds	69.0	49.5	47.0	--
Western hemlock:				
Duff	22	18	16	18.7
Douglas-fir wood	48	36	12	32.0
Spruce wood	58	14	18	30.0
Hemlock wood	28	28	14	23.3
Average, all seed beds	39.0	24.0	15.0	--
Western redcedar:				
Duff	30	10	6	15.3
Douglas-fir wood	32	36	16	28.0
Spruce wood	28	36	16	26.7
Hemlock wood	14	38	14	22.0
Average, all seed beds	26.0	30.0	13.0	--
Pacific silver fir:				
Duff	30	28	12	23.3
Douglas-fir wood	26	38	12	25.3
Spruce wood	18	30	18	22.0
Hemlock wood	14	22	12	16.0
Average, all seed beds	22.0	29.5	13.5	--

[1/] Analysis of variance indicated significant differences among shade and seed bed treatments but no significant seed bed-shade or species-shade interactions. Individual treatment averages were not compared.

Table 6.--*Average survival of germinated seeds in the field, by species, seed bed material, and shade treatment*[1/]

Species and seed bed	Shade treatment			Average, all shade treatments
	Light	Moderate	Heavy	
	Percent			
Douglas-fir:				
Duff	92	100	71	87.7
Douglas-fir wood	97	98	64	86.3
Spruce wood	83	100	89	90.7
Hemlock wood	95	83	49	75.7
Average, all seed beds	91.8	95.2	68.2	--
Sitka spruce:				
Duff	73	78	20	57.0
Douglas-fir wood	64	93	25	60.7
Spruce wood	72	80	8	53.3
Hemlock wood	53	67	0	40.0
Average, all seed beds	65.5	79.5	13.2	--
Lodgepole pine:				
Duff	94	100	20	71.3
Douglas-fir wood	87	91	21	66.3
Spruce wood	88	100	26	71.3
Hemlock wood	61	88	0	49.7
Average, all seed beds	82.5	94.8	16.8	--
Western hemlock:				
Duff	40	100	0	46.7
Douglas-fir wood	49	88	66	67.7
Spruce wood	40	75	33	49.3
Hemlock wood	81	72	12	55.0
Average, all seed beds	52.5	83.8	27.8	--
Western redcedar:				
Duff	35	62	0	32.3
Douglas-fir wood	21	61	25	35.7
Spruce wood	40	84	17	47.0
Hemlock wood	25	32	0	19.0
Average, all seed beds	30.2	59.8	10.5	--
Pacific silver fir:				
Duff	62	100	28	63.3
Douglas-fir wood	65	88	61	71.3
Spruce wood	73	80	50	67.7
Hemlock wood	100	67	83	83.3
Average, all seed beds	75.0	83.8	55.5	--

[1/] Disproportionate subclass frequencies, percentages based on unequal numbers, and unequal variances made statistical analyses of these data impractical.

Douglas-fir wood than on other seed beds. Duff produced the tallest and heaviest seedlings (tables 7 and 8). Root lengths were not significantly affected by seed bed material (table 9).

Germination of all species was poorest in heavy shade and best in light or moderate shade (table 5). Survival was poorest in heavy shade and best in moderate shade (table 6). Shading did not significantly affect seedling heights (table 7), but it did affect root lengths--roots were shorter in heavy shade (table 9). Total seedling weights were also affected by shade intensity. Seedlings of all species except lodgepole pine were heaviest in light and moderate shade and lightest in heavy shade. Lodgepole pine seedlings were heaviest in light shade and lightest in moderate and heavy shade.

Inherent growth differences made species comparisons difficult, but lodgepole pine and Douglas-fir seemed best able to utilize light shade. Pacific silver fir seemed best able to tolerate heavy shade and was least affected by the seed bed differences.

The contrasting effects of seed bed and shade on seedling heights and root lengths constitute the most important results of this field experiment. All species responded similarly. Seedling heights were significantly affected by seed bed but not by shade. Root lengths were affected by shade but not by seed bed. These contrasting responses to shade and seed bed treatments resulted in higher shoot-root ratios for heavily shaded duff than for the other treatment combinations. Higher shoot-root ratios benefit seedlings growing in shady, moist habitats by increasing photosynthesis per unit of total seedling weight (Borman 1958). The observed occurrence of heavily shaded native conifer seedlings only on thick duff accumulations may be the result of a seed bed-induced higher shoot-root ratio that is essential for survival in low light conditions.

Table 7.--*Average height of largest surviving seedling in the field, by species, seed bed material, and shade treatment*[1]

Species and seed bed	Shade treatment			Average, all shade treatments
	Light	Moderate	Heavy	
	- - - - - - - - - - *Centimeters* - - - - - - - - - - - -			
Douglas-fir:				
Duff	11.7	9.3	5.9	9.0
Rotten wood[2]	4.8	4.1	5.0	4.6
Average, all seed beds	8.2	6.7	5.4	--
Sitka spruce:				
Duff	2.2	3.5	2.0	2.6
Rotten wood[2]	1.3	1.6	2.0	1.6
Average, all seed beds	1.8	2.5	2.0	--
Lodgepole pine:				
Duff	8.4	6.1	4.0	6.2
Rotten wood[2]	4.7	4.2	4.3	4.4
Average, all seed beds	6.6	5.2	4.2	--
Western hemlock:				
Duff	3.7	4.1	--	--
Rotten wood[2]	1.9	1.9	1.5	1.8
Average, all seed beds	2.8	3.0	--	--
Western redcedar:				
Duff	4.3	4.0	--	--
Rotten wood[2]	2.0	1.5	1.2	1.6
Average, all seed beds	3.2	2.8	--	--
Pacific silver fir:				
Duff	3.2	3.5	2.5	3.1
Rotten wood[2]	2.7	2.9	2.9	2.8
Average, all seed beds	3.0	3.2	2.7	--

1/ Averages within the same rectangle are not significantly different.

2/ Average, all 3 wood species. They did not differ significantly.

Table 8.--*Average weight of largest surviving seedling in the field, by species, seed bed material, and shade treatment*[1]

Species and seed bed	Shade treatment: Light	Shade treatment: Moderate	Shade treatment: Heavy	Average, all shade treatments
	- - - - - -	- - - Grams	- - - - - -	- - - - - -
Douglas-fir:				
Duff	0.568	0.389	0.024	0.327
Rotten wood[2]	.173	.111	.025	.103
Average, all seed beds	.370	.250	.024	--
Sitka spruce:				
Duff	.032	.039	.003	.025
Rotten wood[2]	.015	.016	.002	.011
Average, all seed beds	.024	.028	.002	--
Lodgepole pine:				
Duff	.752	.310	.009	.357
Rotten wood[2]	.230	.123	.012	.122
Average, all seed beds	.491	.216	.010	--
Western hemlock:				
Duff	.052	.063	--	--
Rotten wood[2]	.019	.020	.002	.014
Average, all seed beds	.036	.042	--	--
Western redcedar:				
Duff	.057	.050	--	--
Rotten wood[2]	.011	.012	.002	.008
Average, all seed beds	.034	.031	--	--
Pacific silver fir:				
Duff	.185	.137	.025	.116
Rotten wood[2]	.093	.122	.028	.081
Average, all seed beds	.139	.130	.026	--

[1] Averages within the same rectangle are not significantly different.

[2] Average, all 3 wood species. They did not differ significantly.

Table 9.--*Average root length of largest surviving seedling in the field, by species, seed bed material, and shade treatment*[1]

Species and seed bed	Shade treatment			Average, and shade treatments
	Light	Moderate	Heavy	
	- - - - - - - - - - *Centimeters* - - - - - - - - - -			
Douglas-fir:				
Duff	24.4	20.3	8.4	17.7
Rotten wood[2]	21.2	20.0	9.7	17.0
Average, all seed beds	22.8	20.2	9.0	--
Sitka spruce:				
Duff	8.6	9.8	3.0	7.1
Rotten wood[2]	7.7	7.2	3.2	6.0
Average, all seed beds	8.2	8.5	3.1	--
Lodgepole pine:				
Duff	23.9	12.7	1.9	12.8
Rotten wood[2]	23.8	18.9	5.3	16.0
Average, all seed beds	23.8	15.8	3.6	--
Western hemlock:				
Duff	15.5	14.5	--	--
Rotten wood[2]	10.7	12.3	4.0	9.0
Average, all seed beds	13.1	13.4	--	--
Western redcedar:				
Duff	16.7	15.7	--	--
Rotten wood[2]	10.4	11.1	3.2	8.2
Average, all seed beds	13.6	13.4	--	--
Pacific silver fir:				
Duff	19.8	19.6	6.8	15.4
Rotten wood[2]	16.2	16.2	7.6	13.3
Average, all seed beds	18.0	17.9	7.2	--

1/ Averages within the same rectangle are not significantly different.

2/ Average, all 3 wood species. They did not differ significantly.

SUMMARY AND DISCUSSION

Nutrients are more abundant in duff than in rotten wood. Coastal tree seedlings grow larger in duff than in rotten wood, even when extra nutrients are added. However, seedlings are usually larger and more abundant on rotten logs than on the duff-covered forest floor under coastal conifer stands where there is less than 40 percent full sunlight. This apparent paradox seems to be the result of differential duff accumulation. Duff layers accumulate on both rotten logs and soil, but they are thicker on those rotten logs that support seedlings than they are on mineral soil.

Where more than 40 percent full sunlight occurs under coastal stands, duff-covered soil and rotten logs seem to be equally suitable seed beds. This apparently results from better root growth--seedling roots grow longer in light shade than in heavy shade. The extra nutrient concentrations present in the thick duff layers that accumulate over rotten wood seem to be essential where heavy shade limits root growth and less important where light shade does not limit it.

The germination and early growth of coastal tree species are not affected differently by differences in organic seed beds, with two minor exceptions. Douglas-fir seed germination is delayed longer than that of other species on duff, and alder seedlings germinating on rotten wood do not develop root hairs or nodules.

Field observations indicate that neither rotten wood nor duff-covered soil are good seed beds where complete removal of the overstory provides full sunlight. Such sun-loving species as red alder are, therefore, not usually found on duff seed beds, even though they grow well on duff when supplemental moisture is supplied. Organic seed beds are most important in shaded conditions such as those that prevail under a lightly thinned shelterwood stand.

Type of organic seed bed probably does not affect the species composition of forest regeneration under a lightly thinned shelterwood stand in coastal Oregon. Where light shelterwood cutting will result in a shaded seed bed, duff accumulations should be preserved whenever possible. This will benefit all conifer species by providing extra nutrients for the short-rooted seedlings produced under low light conditions.

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